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AGE STRUCTURES AND GROWTH PATTERNS OF *APLODINOTUS GRUNNIENS* IN THE RED RIVER OF THE NORTH, MANITOBA, CANADA

by

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AGE STRUCTURES AND GROWTH PATTERNS OF *APLODINOTUS GRUNNIENS* IN THE RED RIVER OF THE NORTH, MANITOBA, CANADA

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Abstract

A fishery and its components are an integral part of society and contribute not only economically, but also socially and physically to the health and well-being of many countries. There are approximately 12.5 million people who are employed in fishery-related careers, and according to the Wildlife and Sport Fish Restoration, there were over 33.1 million people who fished recreationally. To successfully manage a fish population, one must have a well-rounded knowledge about the species and the environment it inhabits. There is very little previous research done on the growth of *Aplodinotus grunniens,* otherwise known as freshwater drum (FWD), making it a complex species to manage with insufficient knowledge. The objective of this study was to establish an age structure and growth patterns for 145 FWD in the Red River of the North, Manitoba, Canada. This information will contribute to the knowledge base of FWD for fish biologists and managers as they hope to better understand different dimensions of a fishery that may inhibit growth and age structure. Using a calcified bone structure in the inner part of FWD head, called the otolith, were used to age the fish by counting the number of annuli the otolith presents and back-calculating the length of the fish at each age using the Dahl-Lea equation. The results were then analyzed and compared to two sample populations from Lake Erie and ancient fossilized FWD from an ancient Indian Middens. In conclusion, the FWD in the Red River measured much larger than FWD in Lake Erie and were much older, indicating that they grew far slower. Overall, the fossilized ancient FWD were much larger than the drum sampled in the Red River. With these results, a better understanding of the aging and growth may contribute to the knowledge base of FWD to fish biologists and managers.

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Acknowledgements

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Introduction

A fishery and its components are an integral part of society and contribute not only economically, but also socially and physically to the health and well-being of many countries. There are approximately 12.5 million people who are employed in fishery-related careers, and according to the Wildlife and Sport Fish Restoration, there were over 33.1 million people who fished recreationally (Cochrane 2011). A fishery is a place where fish are reared for commercial or recreational purposes, and they have three main components; the organisms (fish), the people, and the habitat. Managing fish in a fishery is the most important factor. One must also look at the taxonomy and ecology of the fish, as well as population dynamics. People are not often thought of as a component to a fishery, however humans are important in the regulation of laws and the planning of managing a fishery, for example, setting a catch limit or purchasing and distributing fishing licenses. The fishery habitat is typically the most important factor in a healthy and successful fishery. Without good water quality and proper management, sustaining fish life is extremely difficult or in some cases not possible at all. All three of these components rely on one another to be successful and without one of these components, the entire fishery would fail.

To successfully manage a fish population, one must have a well-rounded knowledge about the species and the environment it inhabits. This is very important to maintain the sustainability and economical profit of a population. There are several alternative theoretical relationships between population resilience, variability, and stress; however, a change in community composition will cause large changes in that ecosystem. Overharvest can be an issue for the sustainability for fish populations, which would lead to ecologic disaster (Hyman and Pimm 2011). There is very little previous research done on the growth of *Aplodinotus grunniens,* otherwise known as freshwater drum (FWD), making it a complex species to manage with insufficient knowledge. These species are particularly susceptible to overharvest as will be explained later. The overarching goal of this research project was to contribute new findings to the previous knowledge of age structures and growth patterns of FWD so that this species will be easier to understand in a dynamic ecosystem. The objective of this study was to establish an age structure and growth patterns for FWD in the Red River of the North, Manitoba, Canada. This information will contribute to the knowledge base of FWD for fish biologists and managers as they hope to better understand different dimensions of a fishery that may inhibit growth and age structure. FWD is the only member of its family in North America to occur completely in freshwater habitats (NPS 2018). The species is native east of the Rocky Mountains from Canada to Texas (Fuller, et al 2016).

The Red River of the North is a unique river that originates at the confluence of the Bois de Sioux and Otter Tail rivers on the border of North Dakota and Minnesota. It flows north to the province of Manitoba, Canada, emptying into Lake Winnipeg. The watershed area of the Red River is 288,000 kilometer^2 at a length of 880 km (Newton 2018). The Red River is a winding, low gradient, warm-water stream, with the mean temperatures regularly reaching 80°F in the summer and icing over in the winter. The mean annual flow at the beginning of the river in North Dakota is 657 cubic feet per second (cfs) and increases to approximately 8,400 cfs as it dumps into Lake Winnipeg. (Aadland et al. 2005).

Figure 1. Mark Porath with Nebraska Game and Parks Commission with a FWD just below the St. Andrews Dam in the Red River of the North.

What will be assessed in FWD includes the age structures and growth patterns. Age is defined as how many numerical years a fish has lived, while growth is the change in length or weight over time. Length and weight usually increase in correlation throughout a fish's life. It is important to study the size and age composition of a population through time because it describes how the population grows and shrinks as controlled by birth, death, and migration according to *Dr. Martin Hamel's Age and Growth Techniques* presentation. An age structure is a characteristic that ecologists use to measure a population. It is simply a summary of the number of individuals of each age in the population. Age structures are useful in knowing and predicting population growth and they are the basis of age data. This is obtained from calculations of mortality rates, growth rates, and recruitment of fish. Recruitment can be defined as the number of fish that survive to a certain age. Age structures also reveal the mortality of a population, which is shown by a linear decrease after the age of recruitment.

By looking at numerical data and comparing it to previous studies of drum from Lake Erie and an ancient Indian Middens in Indiana, this type of study is quantitative and qualitative. The method that will be expended to determine growth patterns of drum uses a calcareous bone that all fish possess called an otolith. One can age an otolith by counting the alternating translucent and opaque rings, called annuli, on the otolith structure. Using a back-calculation method will allow the length at each age of the fish to be determined, which is described in more depth in the methodology section. Other bodily functions can be used to age a fish, such as scales, dorsal spines, and eye lens (Pegg 2018). Previous research shows that the otolith method is the most accurate back calculating method to aging fish. Scales are deemed less accurate because a fish is born without scales, and therefore the annuli doesn't account for this error (Hamel 2018). In a study, *The Eye Lens as an Age Indicator in FWD* completed by Burkett et al.

(1971), a regression of scale age-lens weight data provided a method using drum eye lens for approximating ages of individual fish. In annual groups, the mean lens weight had no significant changes between the different sexes of drum. Overall, this method has also been deemed less accurate than looking at calcified body structures.

Growth back-calculations from otoliths assume that the relationship between fish and otolith length is linear through time, and the final individual fish-otolith ratios are combined to prepare a fish-otolith regression of the population (Pegg 2018). The equation that will be used to calculate the fishes' length at a certain age is called the Dahl-Lea equation:

$$\textit{Equation 1: } F_i = (S_i / S_c) * F_c$$

where:

F_i=Length of fish at age i

S_i=Length of annulus at age i

S_c=Margin, or radius, of annulus

F_c=Total length of fish at capture

Rather than statistically estimating intercept in the Dahl-Lea equation, an algorithm is used to define individual fish-otolith trajectories that are biologically determined (Klumb et al. 2011). The bias in back-calculations, such as using scales to age fish is eliminated in a different equation called Fraser-Lee:

$$\textit{Equation 2: } F_i = C + (F_c - C) * S_i / S_c$$

where all units match eq. 1 except:

C=Correction for scale formation

Because the method using otoliths will be used, eq. 2 will not be necessary, as there is no correction factor to account for.

Methodology

The methodology used to age the fish was done by looking at the calcareous rings, or annuli, of the otoliths in FWD. At the center of the otolith is a nucleus, and from the nucleus to the first annulus represents the hatching of the fish to age one, while from annulus one to annulus two represents age one to age two, and so forth. If one were to graph the annuli length to fish length, the graph should directly increase. Differences of the average annulus from age one until the radius, or margin, at the time the fish was sampled shows different growth patterns in the fish. In looking at these structures, calcium carbonate is added in layers as the fish grows. Just as a tree trunk has rings expanding from its core, an otolith adds a calcareous ring per year, and each ring

Figure 2. Microscopic image of an otolith showing annuli growth.

represents one year the fish has been alive. Variances could be due to stresses upon the fish, such us temperature alterations in the fish's habitat or prey obstructions.

A sample of FWD fish was collected from the Red River of the North below the St. Andrews Dam, located in Manitoba, Canada. This is a freshwater stream that originates in North Dakota and Minnesota, flowing north and dumping into Lake Winnipeg, Canada (Newton 2018). Fish collection the fish was achieved by using multiple hoop nets that were approximately 1 meter in diameter with 75-mm mesh. A hoop net has cylindrical frames that is covered with mesh. It is anchored to the bank of a water system and traps fish as they swim through. The hoop nets were deployed around 15-kilometers downstream from the St. Andrews Dam in Lockport, Manitoba. After a sufficient sample (n=145) was collected, total length and weight was recorded. A large sample size was necessary to collect to increase precision and accuracy of the representation of the drum population. The drum was then harvested and taken to a lab where the otolith extraction took place.

Figure 3. Map of the Red River of the North. The drum were sampled where the star is located.

The otolith extraction needed to be very precise or the otolith could have been easily broken. There are several routes to get to the otic capsule where three otoliths sit; the astericus, lapillus, and sagitta. The sagitta otolith was selected as the appropriate otolith for aging (Pegg 2018), which lies inside the otic capsule located toward the posterior end of the ventral surface of the skull (Gulf States Marine Fisheries Commission 2003). To remove the otolith, the following process was used (See Appendix A): First, using scissors or a similar sharp tool, the isthmus was cut. The second step was removing the gills, again using scissors or a similar sharp tool. Once the gills were removed, the otic capsule was revealed. Using a knife or surgical scalpel, the chamber was cut open and the sagitta otolith was removed. It was vital that the otolith be completely dry, as any moisture could skew the results.

After the otolith extractions took place, it was cracked at the nucleus to get a sectional view. Next, the otoliths were burnt using an open-flamed candle to integrate a smooth surface and then polished using wet fine grit sandpaper. This step was essential to make the otolith as easily readable as possible. The otoliths were then placed on a slide and viewed with a SMZ-100 microscope, where a picture was taken for further examination at 20x magnification. The radius of each otolith and annuli increment measurements were performed across the medial axis within one millimeter of the sulcus and then recorded. The fish was then aged by counting the number of annuli on the otolith, each ring representing one year of the fish's life. Two other readers also aged the fish and a consensus age was developed to reduce any discrepancies.

Data analysis is the next step that took place. Estimating the length of a fish at various ages provides an estimate of growth, which can be beneficial in determining the quality of habitat and overall mortality rates. Growth was assessed using the Dahl-Lea back-calculation equation, which was discussed earlier (refer to *Equation 1*). The annual growth increment is the difference between the initial length of a fish at the start of a growing season and its length at the end of the year. To find the length at a certain age, the ratio of the annuli in that certain year over the margin (or the last annulus from when the fish was sampled) was determined, which was then multiplied by the length of the fish when it was captured. Fish growth during each year was determined and trends or unusual discrepancies in the growth patterns were assessed. Mean length of the fish at each age was graphed using a X-Y scatter plot to visualize the mean back-calculated length increasing through time. A positive correlation will occur if the population is healthily growing.

After the data were analyzed and comprehended, a literature review was necessary to correlate the growth of drum in the Red River of the North, to drum in other water systems in Lake Erie and ancient Indian Middens. Although there isn't much previous research examining the growth of FWD, it will allow an evaluation to be done on the health assessment of that population. Management implications of the population can be implemented based on the conclusion of this data to increase the value of drum for economic and sustainable purposes.

Results

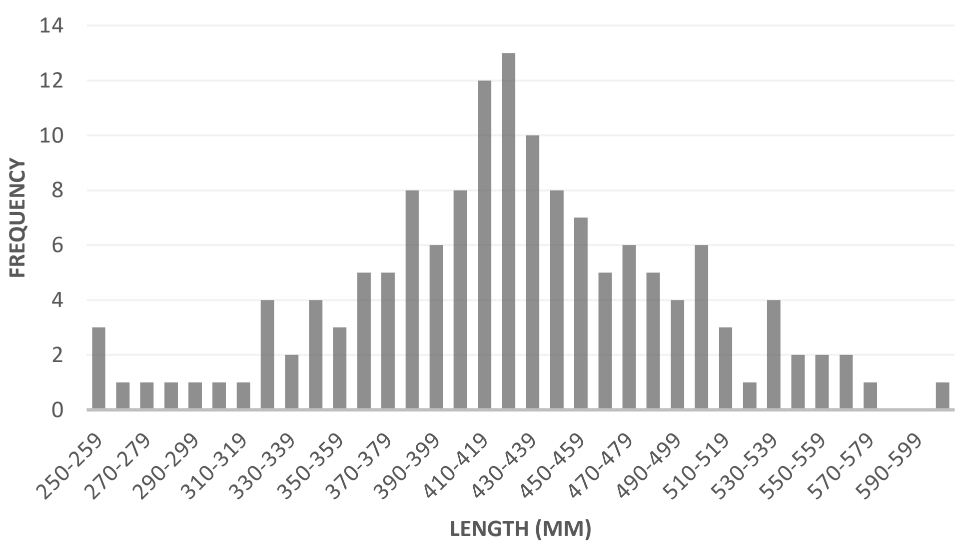


Figure 4. Size frequency of FWD based off the length measured in millimeters. Exact measurements of the fish were taken but were grouped into increments of 10 millimeters

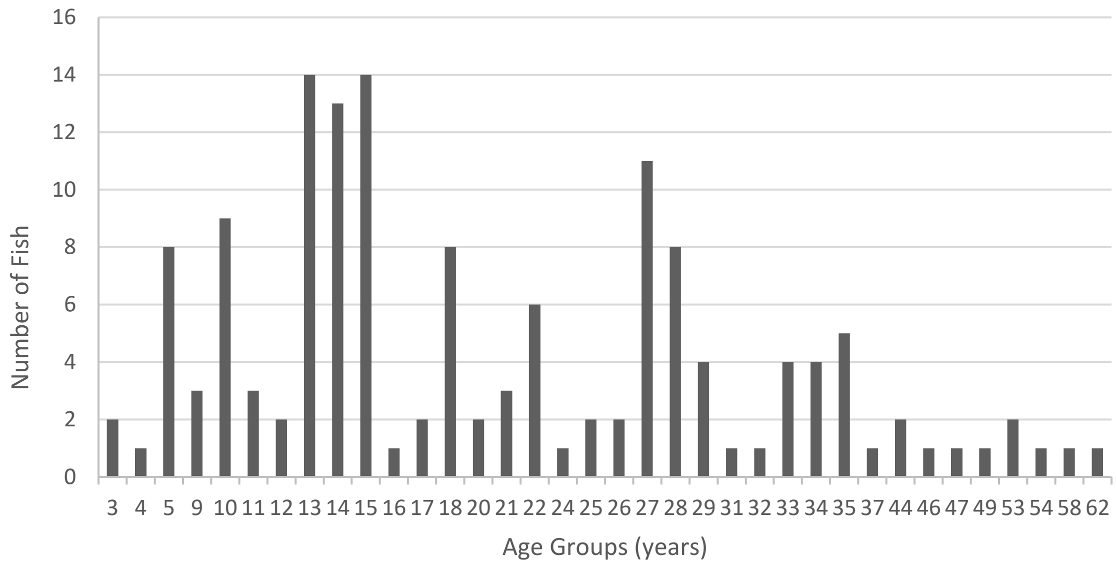


Figure 5. Age structure for FWD. This graph represents the number of fish at each age. Ages not shown on the graph means there were no fish sampled at that age.

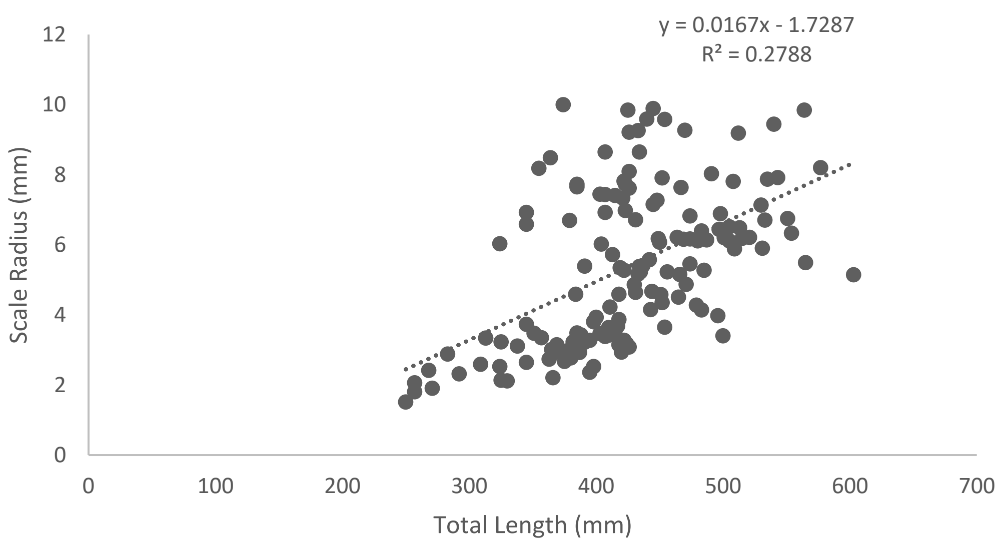


Figure 6. Total body length to calcified structure relation. The scale radius of the otolith, also known as margin, generally increases while the fish length increases as it ages.

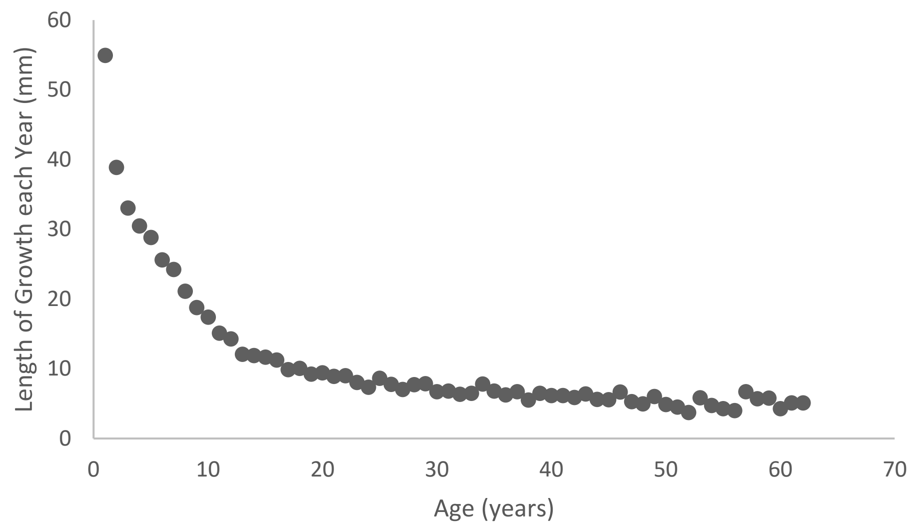


Figure 7. Mean growth increments at each age for FWD. By subtracting the previous back-calculated length at a certain age to that current length, an average growth increment was found.

Discussion and Conclusion

It was found that radii grow in proportion to age and growth in FWD of the Red River, as mentioned earlier. As drum get older, the amount the fish grows each year decreases over time and eventually levels out when the fish reaches sexual maturity around age 10. This is due to the fish putting less energy into growth and more energy into sexual reproduction.

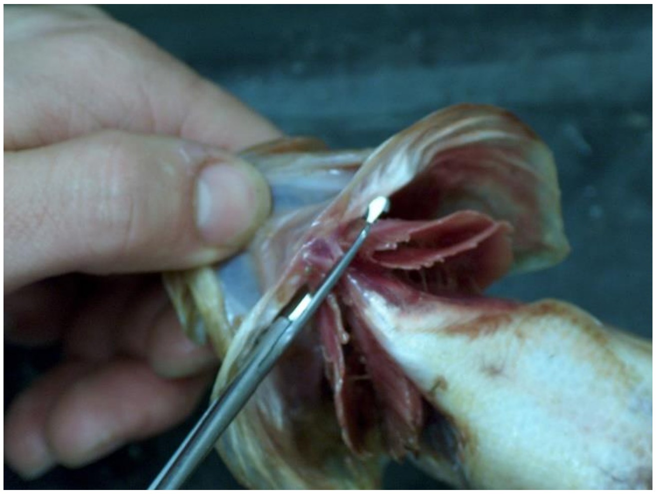
In the Red River, the sample population of FWD ranged from ages 3 to 62. This came to a surprise, as a much larger sample size of FWD (n=1958) in Lake Erie only ranged from ages 1 to 14 (Edsall 1967). This finding could be caused by biological differences between the Red River and Lake Erie such as nutrient content and habitat. Further research is needed to investigate this finding. The average length of FWD in the Red River was 388 mm while the average length of FWD in Lake Erie was 196 mm (Edsall 1967).

However, when comparing growth of ancient fossilized FWD found in an Indian Middens in Indiana, the body lengths ranged from 200 to 700 mm with majority measuring above 500 mm (Witt 1960). FWD body length in the Red River ranged from 200 to 500 mm with the majority measuring below 400 mm. This finding could be due to the northern location of the Red River and colder water temperatures.

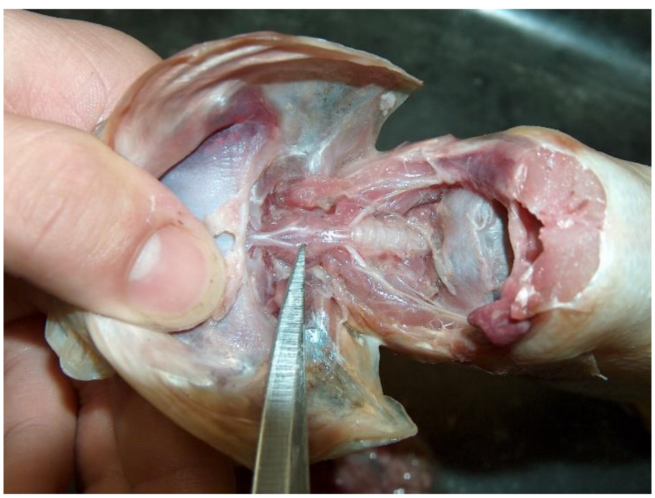
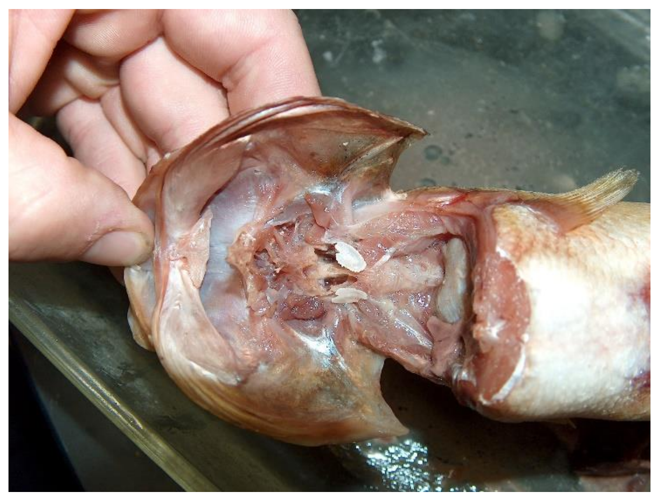
In conclusion, the FWD in the Red River measured much larger than FWD in Lake Erie and were much older, indicating that they grew far slower. This outcome makes FWD in the Red River susceptible to overfishing where harvest occurs because anglers prefer to harvest larger fish which prevents them to reach sexual maturity. This makes the fish unable to reproduce faster than they are being harvested, leaving an inconsistent population. Overall, the fossilized ancient FWD were much larger than the drum sampled in the Red River.

With these results, a better understanding of the aging and growth may contribute to the knowledge base of FWD to fish biologists and managers. Currently, there is ongoing research on the migration of FWD in the Red River. If this study was to be replicated, more parameters of FWD should also be looked at such as mortality or reproduction factors. This could provide a better understanding of a very important, yet underestimated fishery in Manitoba, Canada.

Appendix A




Figures 8 and 9. The location and cutting of the isthmus, and subsequently removal of the gills.

Figures 10 and 11. Location of otic capsule and sagittal otolith removal.

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